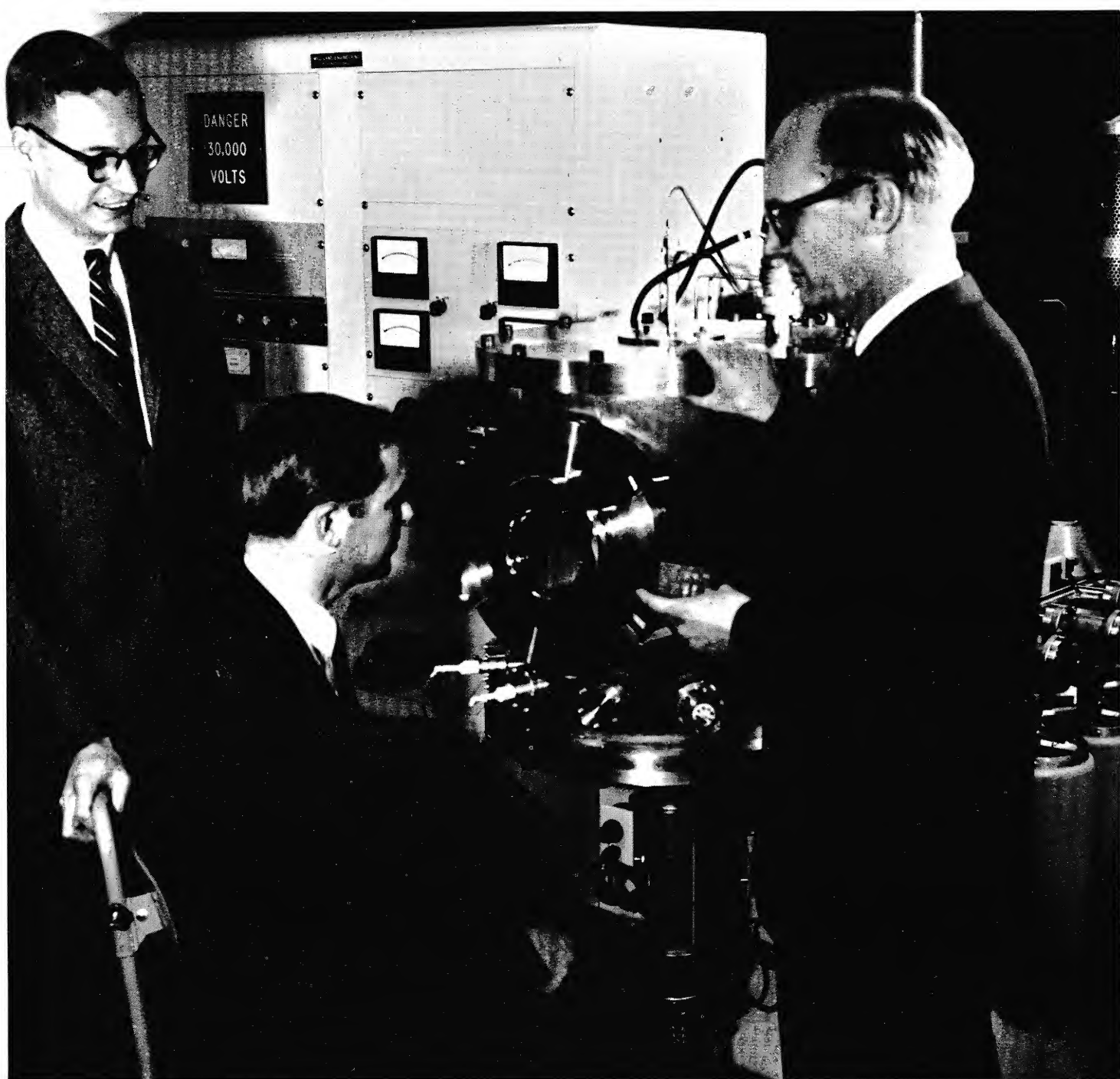


See quote, first page.



MAY 1966

**EVALUATION
AND
PURCHASING**

ELECTRONIC

A MACTIER
PUBLICATION

PROCUREMENT

3C Management Evaluates IC/Thin Film Processes

(Reprinted from ELECTRONIC PROCUREMENT, May 1966)

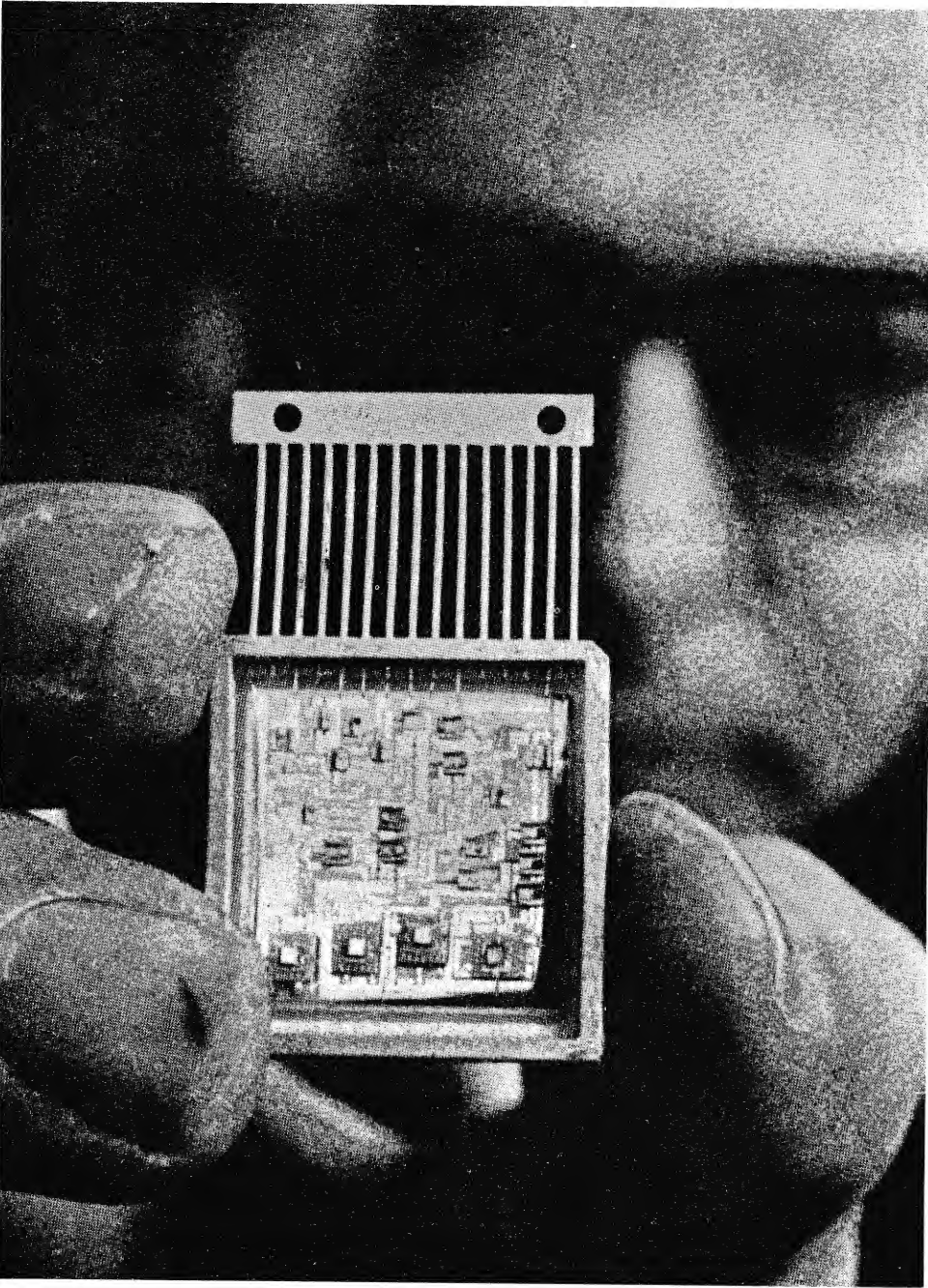
Integrated Circuit Case Histories

More Performance for Less Dollars

THERE'S FAR TOO MUCH EMOTION back of buying integrated circuits, says Stan Olsen, not unemotionally. Olsen, as module products manager at Digital Equipment Corp., says DEC must deliver thoroughly reliable, large quantities on time at best prices. The silicon monolithic integrated circuit is considered too risky from a reliability and delivery point of view to be used by DEC today. Olsen does not rule ICs out. He says there are no such things as totally integrated circuits; everything is a hybrid of some sort. His modules will use monolithic silicon chip circuits when they are clearly the best solution. In the meantime, DEC modules are either all discrete or a combination of discrete and thick-film ceramic substrates containing "chip" diodes or transistors. DEC modules use lots of capacitors. Olsen, to drive home a point, says: "God gave man the capacitor. To not use the capacitor is to sin against God, isn't it?"

Because the process for making monolithic ICs can't produce capacitors readily, a lot of complex circuitry has to result, Olsen claims. But so what if non-capacitor circuitry is more complex, many others say. Scientific Data Systems, for example, points out that with integrated circuit technology buffering can be added to AND/OR gate structures, without increasing the cost over simpler NAND and NOR counterparts. Tradition-bound methods need not be used.

J. T. Suran of GE will not get hung up on capacitors. Last December at a JFD sponsored symposium on the future of components he conjectured, "A highly advanced electronic civilization, perhaps one on a distant planet, will never have heard of capacitors, resistors or transformers. These functions will be performed by a different technology." IC technology, which batch manufac-



SILICON MONOLITHIC ICs are incorporated into larger thin film circuits at Collins Radio. The hybrid shown is a stair step voltage generator designed for a frequency synthesizer. Collins expects to use similar modules in commercial communications equipment later in 1966.

Our Findings In Capsule

Economics

How does the cost of integrated circuits compare with that of discrete component circuits?

About 25 percent less for standard digital logic circuits, taking into account savings in PC board assembly time.

Is extra time and money spent in testing IC's?

Very little. Generally, 100 percent testing by the vendor is part of the purchase document and purchase price and is not repeated by user. Careful sampling is practiced by some. Amount of sample testing is expected to decrease.

How much direct engineering cost did you charge up to the conversion?

Rarely does anybody compute extra engineering effort. Surprisingly little time is spent in learning or "relearning." ICs are generally used to produce new equipments with extra features. No one found using standard IC circuits difficult or tricky — except for transients. For protection against burn-out or damage, line transients had to be filtered out.

More time is needed to do the PC layout because each package has more leads. "Think" time is needed to decide on the new module size, type connector, etc. Such decisions are "one timers"; once made they apply to new designs.

Are there indirect or surprise costs found with ICs?

Not that any of our respondents recall. Most felt sure there were some indirect savings since fewer parts are inventoried and handled. Except for the computer companies, separate microelectronic labs are not maintained.

Performance & Design

Did you make performance sacrifices or did performance improve?

Equipments or systems incorporating ICs generally boast more features than did predecessor equipment built with discrete components. Generally more complex jobs were done with no increase in cost or equipment size. For example, Packard Instrument's liquid scintillation spectrometer now contains a complete computer as part of the counter. The IC logic modules 3C markets offer 5MHz capability at 200 kHz prices. However, if you need 10 MHz clock rates you will probably have to use discrete or film circuits.

Was noise immunity a problem?

No. IC circuits are rated about the same as discrete component circuits. IC circuits cannot tolerate the voltage spikes that transistors can. Therefore power supply filtering is necessary.

Did you tend to stay with the same logic type used with conventional circuits (RTL, DTL) or did you switch to newer IC circuits such as TTL?

This question wasn't particularly meaningful to users. Most bought a logic function rather than a philosophy and just how it was accomplished inside the can or package wasn't of prime importance. What was important was how many packages or circuits were needed to complete the system.

Since TTL wasn't generally available 12 to 18 months ago, equipments now appearing on the market use earlier logic forms. Some users report they are working with TTL because fewer packages are needed to do the job.

What package did you pick and why?

Something compatible with the existing method of fabricating and assembling PC boards. TO-5 cans were okay until the more convenient dual-in line plug-in package arrived on the scene. Current trends require more than the ten leads a TO-5 can accommodate. The dual-in line package with 300 mils between rows is most popular at this time. Some users have Texas Instruments put a 45° bend in the straight leads of its plug-in package (which are normally 200 mils between rows) so that the leads can be probed from on top.

At least one user has designed around flat packs having developed a soldering machine which solders all leads simultaneously.

Most PC boards are dual-sided. Computer companies may use a 3- or 4-layer board with one layer a ground plane to achieve optimum shielding and transmission characteristics.

Procurement

How many suppliers did you consider?

Generally three or four. Those buying large volume for computer production visit all suppliers periodically.

How many sources did you select?

Unlike military users, most commercial users are relying on a single source, at least initially. Buyers for larger computers try harder for multiple sources and try to split orders early.

A buyer sometimes purchases different circuits from different sources. Analog circuit sources, for example, may be different from digital logic circuit sources.

Who participates in vendor surveys?

The project engineer and top engineering management (or corporate management in the case of smaller companies) for sure. In all but the smaller companies the Purchasing Director is the chief negotiator. Quality control generally figures in, especially after the sources have been narrowed to three or four.

What are day to day relationships between customers and suppliers?

Intimate — at least at the outset. There are many problems that crop up regarding interpretation of specifications and tests, delivery and changes. The customer is logically represented by a purchasing manager; the seller by a program manager.

Marketing

Does the incorporation of ICs help sell the equipment?

Not because of the use of ICs per se. Their use must enhance the product in some utilitarian way. The customer of a commercial product generally couldn't care less what's inside.

tures thousands of active devices at a few cents each, thus offers a new but an extremely low cost approach to digital design.

A great many companies find ICs an economical way to go, and engineers of these companies will deny that emotion is swaying them. Among the commercial users are many module logic producers. We already mentioned SDS. Another is 3C, generally considered the largest digital logic module supplier. Data Technology is another large module producer going "all out" for silicon monolithic ICs. Other module users who have been producing IC versions for over a year are Abacus-Whittaker, Digital Products, Gulton, Microsystems Components, Philco (WDL), and Walkirt. Recent converts are listed later under the heading, "Joining the Parade."

If Digital Equipment Corp., even for a moment, feels it is bucking the trend, it undoubtedly gets psychological support from knowing that its approach parallels that of IBM. Although IBM, too, hedges by stating that silicon monolithics will be used when commercially justifiable, it currently "flips" discrete transistors and diodes onto the ceramic circuit. Presumably IBM could flip on IC packages.

But let us get out of the forest of the module market to see the bigger impact of integrated circuits. Following are some equipments systems that use ICs for economical reasons.

- The DDP-124 high speed general-purpose 24-bit digital computer by 3C.
- The Model 92 computer by SDS (March, 1965) and the recent Sigma 7 scientific-business computer series.
- The new Burroughs B2500 and 3500 data processing systems (featuring master control programs for on-line, real time and time share operation). Earlier models 5500 and 8500 also used ICs.
- A new vote counting machine by Cubic Corp.
- A liquid scintillation counter by Packard Instrument.
- Numerical contouring control Model 3000 by Bunker-Ramo.
- A desk calculator by Dero Research and Mfg. Co.
- An integrated circuit tester by

Monitor Systems Inc.

- A portion of an RCA television circuit.

The above list is by no means a catalog of all equipment that has gone to IC for reasons of economy. It does represent those investigated by ELECTRONIC PROCUREMENT.

The only piece of test equipment in the above list is the tester by Monitor Systems. There are many other examples, but most of them are the work of divisions associated with semiconductor manufacturers.

We do not, therefore, include them in the first list. Those reported on later in the report include:

- An integrated circuit tester model 553 by Texas Instruments
- An analog to digital converter by Texas Instruments

There is every reason to believe that several new pieces of test equipment using ICs will be announced before the year is out. At the moment these projects are hush-hush for various proprietary reasons.

To try to separate emotion from hard dollars and cents in the switch from conventional circuitry to integrated circuits, EP asked the new IC users a series of questions. The questions posed and the composite answers of all who replied are boxed off on page 31.

Details of how ICs are viewed and used by individuals are reported company by company. No military case histories are included.

3C Cautious Leadership

THE COMPUTER CONTROL COMPANY boasts that it is the world's largest supplier of digital logic modules. It now offers a full line of monolithic IC digital logic modules trademarked μ -Pacs.

"Are μ -Pacs really less expensive than discrete component modules? Have you sacrificed performance?" we asked. Bob Baron, director of module products, replies, "We offer 5 MHz performance at 200 kHz prices."

Baron says 3C design objective was to offer the best cost-performance trade offs across the whole

digital line. Smaller size and power are side benefits.

ICs do save money, Baron said, when all factors are considered: circuit cost, assembly cost, power supply and power distribution costs and incoming assembly costs.

3C did not move lightly into the use of ICs. The company has been operating its own microelectronics laboratory. In fact the ICs now purchased from Texas Instruments, Westinghouse and Sylvania are all based on 3C designs.

T. Paul Bothwell, vice president, engineering, says, "Monolithic integrated circuitry was adopted after a careful evaluation of all the many concepts of microcircuit development. . . . The lab is continuing to do advanced device and process development work."

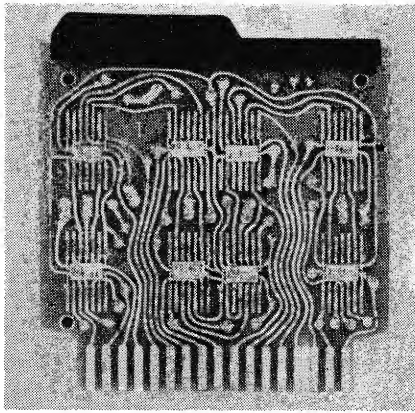
The in-house capability is now being used to evaluate structures using silicon monolithic and evaporated thin-film techniques. (See cover for a photo of 3C's electron beam deposition equipment for making thin films.)

Bothwell says the monolithic circuit cost barrier is reduced "to the level of discrete components." Most new products developed at 3C will feature "total monolithic integrated circuits" according to Bothwell.

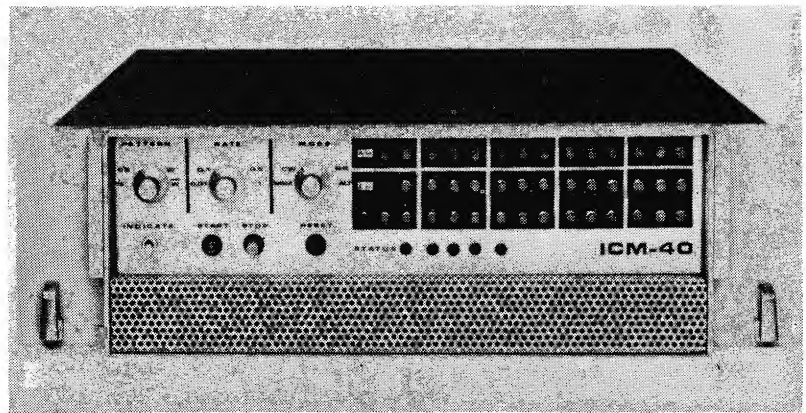
Equipment currently using IC modules include the new DDP-124 general purpose computer and ICM-40 core memories. 3C is working on a scratch pad memory that will use ICs.

Getting a reliable product, or rather getting an unreliable product, is not a major worry at 3C. Fabrication of ICs is still viewed as a black art and Baron realized there might be batch to batch variations, even from the same vendor. However, careful test specs have been written and 3C relies on 100 percent vendor testing to catch batches that have gone awry. The company samples only incoming shipments. Because 3C knows the fabrication process cold as a result of its own lab, it feels it knows what is going on at the vendor's plant. Although 100 percent vendor testing is required, 3C tries to keep testing costs to a minimum by testing only critical parameters.

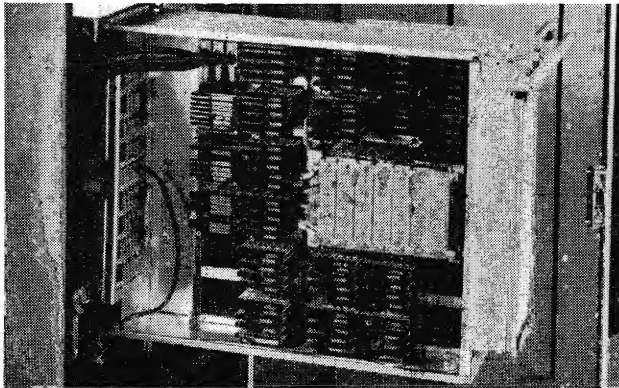
Converting the module line from conventional component to ICs was not a major task. "Design rules are about the same," Baron reports.



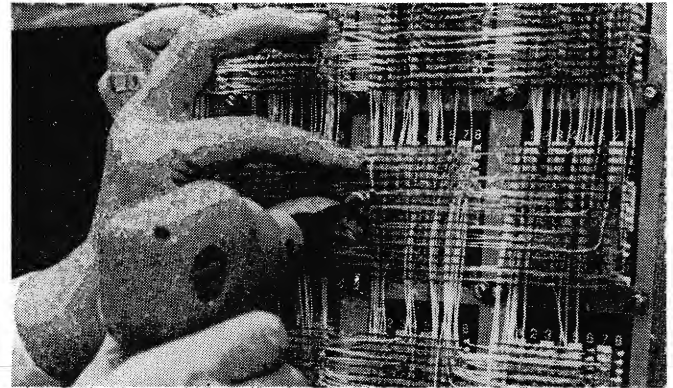
SHIFT REGISTER integrated circuit module from 3C. One of many modules offered.



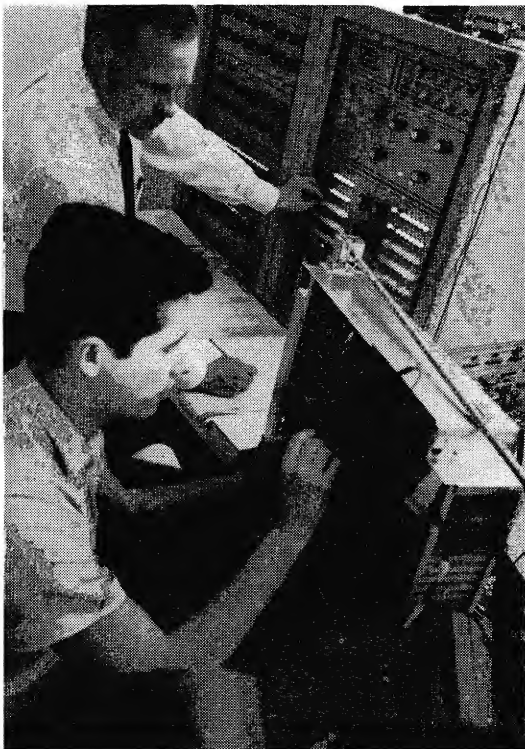
FAST CORE MEMORY (ICM-40) by 3C operates in 1 microsecond full cycle. Access time is less than 500 nanoseconds.



THE CORE MEMORY is designed for both horizontal and vertical mounting — easy to accomplish because height is only 5-1/4 inches.



THE MODULES are designed for hand wire wrapping of back plane.



USE OF integrated circuits has not increased test cost at 3C.

There were different rules for fan out and connector pin assignment procedures. The company's standard component S-Pacs do not correspond one for one with the μ -Pac line. This is largely because the μ -Pac modules can contain more circuitry.

A major design task in converting to IC is to determine the module size. This is a function of the connector, the number of components and the number of interconnections that can be made on a dual-sided PC board.

The μ -Pac board size is about half that of a discrete component board. A 34 pin Varicon Elco connector is used. Such a board can handle up to 22 flip-flops (compared to 6 F-F maximum on the earlier boards). By controlling the board and the connector, 3C can make up module "sticks" that will behave predictably in a system.

Contrary to the practices of most companies, 3C uses a flat pack. The company developed its own soldering device to solder all

14 leads of the flat pack simultaneously. Baron feels at this stage the package cost of the flat pack is not much more than that of a TO-5 can. The flat pack offers an advantage over the dual-in package, for example, in that the lead lines are shorter (lessening mutual inductance and noise pickup possibilities) and less stray capacitance is associated with the pack. Consequently the flat pack can theoretically operate faster and have more noise immunity than can other approaches.

A further advantage is that the flat package consumes less real estate. Baron also says a designer would have to go to multilayer boards more quickly with plug-in packages because one uses up two sides the moment a plug-in is used.

3C did experience a savings in power suppliers by going to ICs. The new system uses two power supplies as opposed to the three used in the discrete component module system.

Monolithics are not suitable for

every job. 3C does not use them for analog circuits, high precision circuits (clocks use discrete components) or high power circuits.

Initial vendor surveys were made one and a half to two years ago. At first four major suppliers and two smaller suppliers were considered. Technical evaluation reduced the number to two.

Survey teams weighed these factors, reports 3C Procurement Director Charles Brown:

1. technical capability
2. proposed pricing (economic justification)
3. delivery
4. ability to maintain volume shipment
5. engineering assistance

QC didn't participate in early vendor surveys but this was because they already knew what tests should be considered from their lab experience. At 3C the procurement department head and the senior buyer get in the act. "It's three times harder to negotiate a contract for ICs than other semis," Brown reports.

Because 3C is not a giant in the computer field, the company did a little selling of its own to get vendors interested. This was important, Brown feels, in getting vendor understanding.

The company approached vendors with one drawback — it had its own proprietary circuits. (One

of the terms of final negotiations was that the vendor could not divulge or sell 3C circuits to anyone without express permission.)

From the outset 3C wanted dual sources, so it split the initial order. The mix to vendors has varied depending on their ability to deliver. The original vendors were TI and Westinghouse. Since then Sylvania has been added.

One secret of successful vendor relations is knowing key personnel well. Brown likes the arrangement where the vendor establishes a program manager.

Has 3C paid a high price because of its proprietary designs? Brown doesn't think so, but he keeps a sharp eye open for any less expensive standard circuit that might do the job for the company.

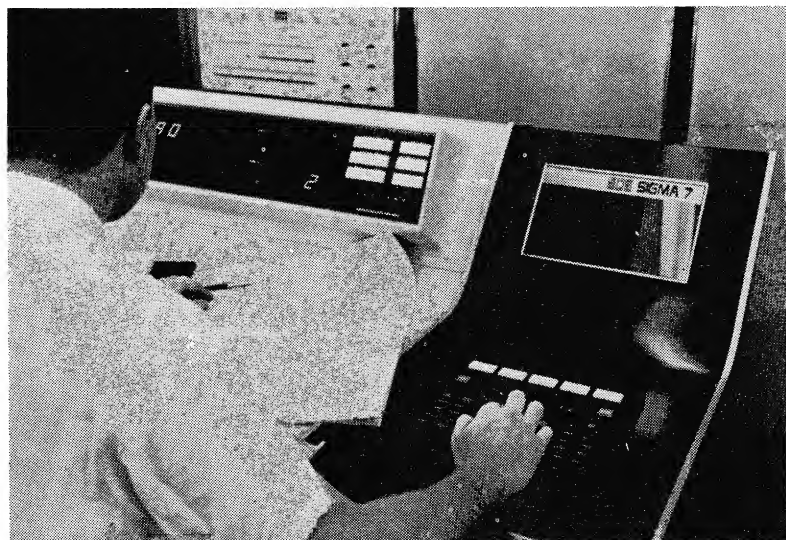
SDS: Pioneer Exploiter Of ICs

THE FIRST COMMERCIAL COMPUTER to use integrated circuits was the Scientific Data Systems Model 92 computer delivered in March 1965. This computer used the company's T Series of modules. From the experience thus gained SDS claims to be expert at module design *and* economics.

From a cost and performance consideration, SDS finds the optimum choice to be a combination of discrete resistor diode gates and integrated flip-flops, buffers and inverters. The integrated circuits cut costs by replacing repetitive clusters of transistors. The diode gates retain flexibility where needed for the gating structures and permit higher noise rejection.

SDS says that on a basis of cost per circuit and average propagation delays, T Series modules are highly competitive. However, their real features cannot be fully appreciated by comparing them with other modules on a circuit-by-circuit basis. It is only in the implementation of a complete system logic function that the merits of these features become apparent. In many systems applications, SDS claims T Series modules can perform the logic task at a fraction of the cost and double the speed of competing types.

The monolithic integrated buffers, inverters and flip-flops designed by SDS allow diode AND/OR structures at their inputs, (instead of the customary NAND circuit). This permits three levels of logic to be performed with a single level of amplification; that is, any element can have two levels of input gates plus outputs paralleled with other elements to implement a third level. Consider



THE NEW Sigma 7 computer by SDS features advanced software. The expanded computing capability of the Sigma 7 without reprogramming is practical because of use of integrated circuits.



the mechanization of the following function:

$$Q = (\overline{AB} + \overline{CD})(\overline{EFG} + H)(\overline{IJK})$$

SDS integrated circuit logic elements permit this function to be translated directly into hardware using only *three* noninverting amplifiers.

Implementing the same logical function using NOR or NAND gates is much more complex and would require *six* or *seven* amplifying circuits.

SDS claims its approach to logic costs is 25 percent less than NAND logic.

No performance sacrifice is conceded by SDS. It claims its ICs handle up to 60 mA of current. This offers a fanout of 14 compared to eight for some monolithics. The high current capability also contributes to high speeds.

The card size of the T series is 4-1/4 by 4-1/4. Double sided cards are used with 52 contacts. SDS uses primarily TO-5 cans but may shift to dual-in line packages for some applications.

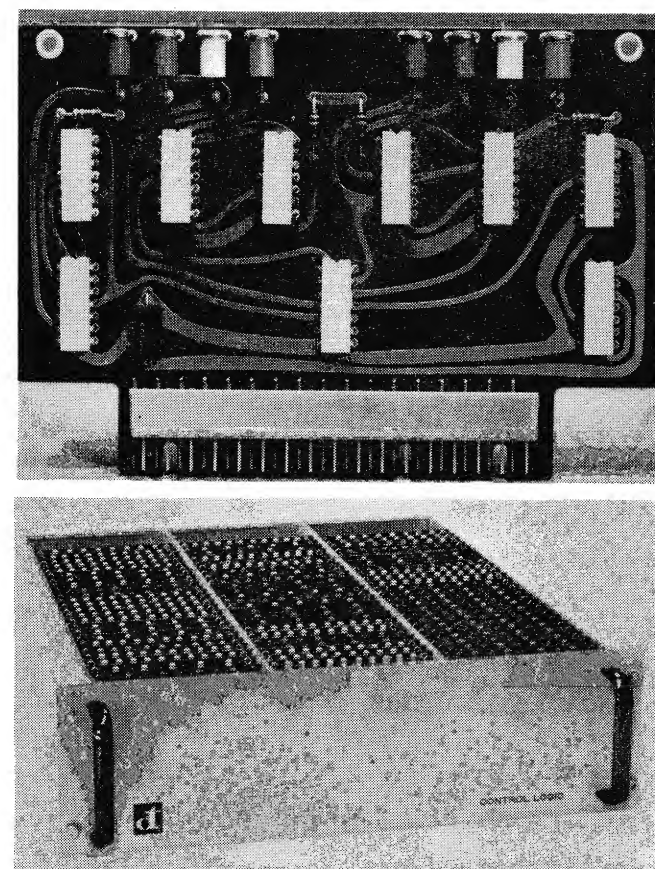
Monolithic circuits are used extensively in SDS's new Sigma 7 computer, billed as a third generation computer. The Sigma 7 features real time, multiprogramming, multiprocessing and time sharing. SDS claims the Sigma 7 will deliver two times more computations per dollar than any other machine in the industry.

A complex IC incorporating 400 components on a single chip is used in the scratch memory. Signetics is one of the suppliers to SDS.

Data Technology: IC Modules Open New Frontiers

DATA TECHNOLOGY CORPORATION claims to be a leader in the module field primarily because of its early use of ICs. The company offers off-the-shelf delivery of a wide selection of IC modules. Peter Dietz, vice president of marketing, provided some frank answers to our questions.

Dietz did not hedge in stating that the actual price of integrated circuits is not as low today as com-



TYPICAL DTC module reveals elegant simplicity of IC modules. Module shown is decade counter which contains two identical and independent counters. Each counter contains four flip-flops in a 1-2-4-8 configuration. Drawer type chassis (below) shows test points (which are color coded) on top edge of board.

parable epoxy transistors. But it is close enough, he said, to warrant a switch for two reasons:

1. Substantial labor is saved in the assembly of the logic modules.
2. The prices of the epoxies have pretty well bottomed out whereas the integrated circuits are just beginning to drop in price.

The Data Technology spokesman also said that although integrated circuits enables one to decrease the size of the board or increase the capacity sometimes there are definite problems to be considered. Some of these are:

- A complete line of cards is essential. This necessitates analog cards and electrochemical, high voltage high current interface cards. Since the vast majority of these use discrete components, the size of the basic logic cards is usually determined by these functions as differentiated from the normal simple digital logical elements, such as NANDS or flip-flops.
- Once the standard size is determined, the packing efficiency for cards employing only logic elements usually turns out to be poor as the cards rapidly become pin limited.
- The optimum utilization of inte-

grated circuits comes when they can be employed in a group on a board to perform a given logic function such as a decade or binary counter, an arithmetic unit or a shift register. This enables one to utilize the space without being pin limited.

Dietz had this to say about performance and design trade offs: "There is no way of getting around the two basic noise inducing formulas— $e = L di/dt$ and $i = C de/dt$. Since you must live with these requirements, it becomes obvious that you want the rise times of the integrated circuits to be as long as possible but short enough to perform all of your logic functions within the time required. You also want the current to be as low as possible yet sufficient to drive your loads. It is also desirable to make the lead length as short as possible and to have a solid bus bar for ground return. All of these factors help reduce noise."

Data Technology was the first module supplier to use the dual in-line package. Dietz says the lead limiting factors of the TO-5 prevent its effective use. The flat pack, on the other hand, although not lead limited, is difficult to replace

during R & D development or in the field. In the future, however, Dietz feels the number of leads will be greatly extended so that larger and more complicated logic functions within one chip can be used.

During Data Technology's original evaluation of sources, it contacted over twenty integrated circuit manufacturers. From these twenty quotations were selected eight companies. From experience Data Technology learned to demand a sample chip so that complete technical evaluation could be made not only of specifications but on the idiosyncrasies of particular devices.

The Engineering department played a very important role in selecting the first vendor. However, during recent months the engineering department evaluates only the product and gives a pass or fail rating. The purchasing department then negotiates with the vendors whose product passed the technical evaluation.

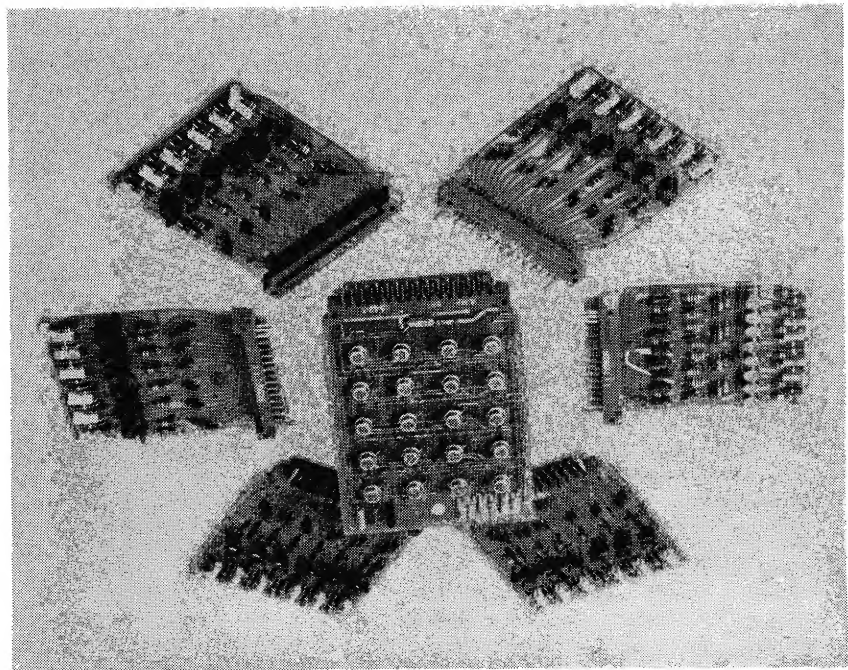
Dietz says the use of integrated circuits on logic modules has opened up new frontiers which are certain to be explored and exploited by many during the coming months.

Cubic Corp: Counts Votes & Profits with IC[†]

THE CUBIC CORP. had by November 1965, built and successfully field tested 90 Votronic Vote Counters using discrete components. Aware that ICs are the wave of the future, they pondered whether the time to convert was at hand. Cubic engineers and management raised four key questions.

1. Are availability and adaptability of present integrated circuits adequate for large scale production needs?
2. Are they economically competitive with discrete components?
3. Are they compatible with existing manufacturing techniques and facilities?
4. Do they offer specific advantages that warrant an equipment redesign effort?

The answer to each question,



A SINGLE CARD containing 20 RTL integrated circuits used by Cubic Corp. replaced as many as six discrete component cards.

after careful investigation, was a definite yes.

The decision to go integrated circuits was not an arbitrary one. In fact, Cubic officials recall few instances in which a single decision was preceded by such an exhaustive program of investigation by both engineering and marketing groups. It was based on the recommendation that only integrated circuits would yield the estimated 25 percent equipment expansion* required to achieve the projected capability and reliability level, while still remaining within the economic boundaries.

To arrive at this recommendation, a group of 20 engineers and technicians was charged with the responsibility of evaluating every integrated circuit that could be purchased. Concurrently, systems designers analyzed the capabilities of integrated circuits to perform all of the necessary functions of the

expanded system, and purchasing people researched the price structures and the potential availability of the various product lines.

The conclusions clearly pointed towards integrated circuits, though not without a list of anticipated problems.

The circuits group said ICs could perform the required decision making functions — but they worried about potential noise problems due to the fixed logic swing that was considerably smaller than that of the existing discrete component circuitry.

Yes, said systems design, ICs should improve reliability — but it was emphasized that about 10 percent of the system still had to rely on discrete components because linear IC circuits to adequately drive peripheral equipment (readouts, etc.) were not available.

Yes, predicted the marketing group, multisource availability indicated an adequate supply of some IC product lines, but part-for-part price comparisons between integrated and discrete components at the time of the evaluation showed a slightly higher cost for integrated circuits.

The decision to integrate was made by George Tweed, Cubic's vice president and chief engineer,

[†]Most of the Cubic experience was reported by L. Stern of Motorola. An expanded article on the Votronic Vote Counter will appear in a forthcoming issue of the *Motorola Monitor*.

*Field tests highlighted some specific problems with discrete components systems already anticipated. The need for greater reliability was one — a significant number of the units required some adjustment during the in-use period.

The need for improved readout was another — the initial machines provided only a visual readout. The time required to record the count and the possibility of human error in subsequent manual recording clearly indicated the necessity for a supplementary printed readout plus punch-card capability (already under development at Cubic).

and it was based principally on economic considerations. Discrete components, Tweed reasoned, are on the lower, flattening-out portion of their "learning curve." That is, manufacturers have learned to make them at such high yields that further significant price reductions were unlikely. By contrast, the integrated circuits learning curve was still a long way from stabilization.

The production requirements for the vote counter alone (approximately 1500 circuit modules per machine) should reduce the supplier's production cost to a point where a more favorable unit price could be negotiated. Even if immediate price reductions were not available, however, the anticipated savings in other materials and in labor costs were expected to offset any cost differential between discrete and integrated circuit components.

To further insure economic advantages, a line of RTL circuits was selected. These devices adequately satisfied system requirements and were available from several suppliers, providing the advantage of competitive bidding and an abundant supply.

Tweed's judgment proved correct—though not entirely in the way he had anticipated. True, the desired integrated circuits were purchased in production quantities at prices more than competitive with discrete components, but production savings did not come up to expectations. The discrepancy arose in the board assembly process. The discrete component ver-

sions of the machine consisted of 230 circuit cards. Each card housed a relatively simple basic circuit so that the entire system could be built with only 15 different types of card layouts. In the IC version, 25 percent greater capability is furnished by only 90 circuit cards, each one housing a far more complex circuit. Of these 90 cards there are 60 different card layouts, with the obvious result that assembly workers do not become as proficient in the assembly of any one card as they were with the simpler ones run in larger quantities.

Moreover, Tweed didn't reckon with the extra caution of his engineers. Being unfamiliar with integrated circuits, extra tests and inspections were initiated up and down the whole line. Incoming inspection, for example, checks all modules, not only in the actual circuit for which it is intended. They also devised a special 12-bit shift register counter test with a 1 MHz clock frequency which every module must pass. The test is so much more stringent than the requirements for actual operation that, if the modules operate satisfactorily in this test jig, there's little possibility of malfunctioning in use.

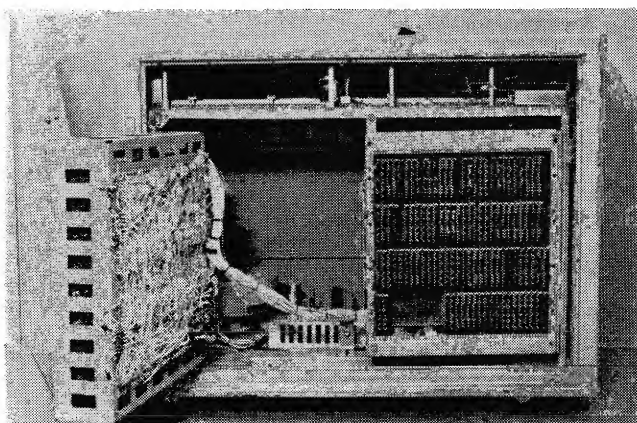
Despite these extra precautions, however, faith in integrated circuits was well justified. Says John Howell, program manager for the vote counter, "We're getting 20 percent more for our money than we could hope for with discrete components, and we've already seen enough to predict a very

gratifying improvement in reliability." At least part of this reliability improvement is attributed to the reduction in heat dissipation by about an order of magnitude. Some of it, according to project engineer Dave Kindig, is the result of a dramatic reduction in the number of interconnecting wire and connector contacts.

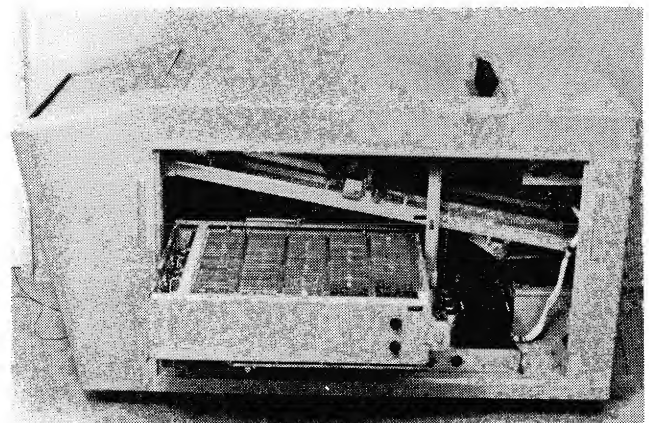
Both Howell and Kindig agree that most of the engineering problems anticipated by the switch to integrated circuits just didn't materialize. "During each step of design and production, they just seemed to evaporate before we even got to them," Howell said.

The decision of flat packs vs TO-5 cans, for example, wasn't much of a contest with the nod going to TO-5's for both economic and production compatibility reasons. A tougher decision was the one concerning the amount of circuitry to be placed on a printed-circuit card. Space was not a real problem. The paramount need was for long term reliability and ready serviceability (you just can't hold up an election count because of some mechanical or electrical failure). Too, the cost of spare parts became a factor since a five-year service guarantee goes with each vote counter, and Cubic sends a technical team with a complete set of replacement cards to be on hand at major elections — just in case.

The final analysis prescribed a double-sided board with a 20 package limit per board as being most economical for this application.



THE FIRST vote counter by Cubic used 230 conventional circuit boards in two bays. Open bay shows wiring complexity.



THE IC MODEL of the vote counter features 25 percent greater capacity with only 90 circuit cards.

With a single integrated circuit card replacing as many as six discrete component boards, the resulting space savings not only permitted the addition of 25 percent more capacity, it reduced the initial two-bay system to a single, more compact card drawer.

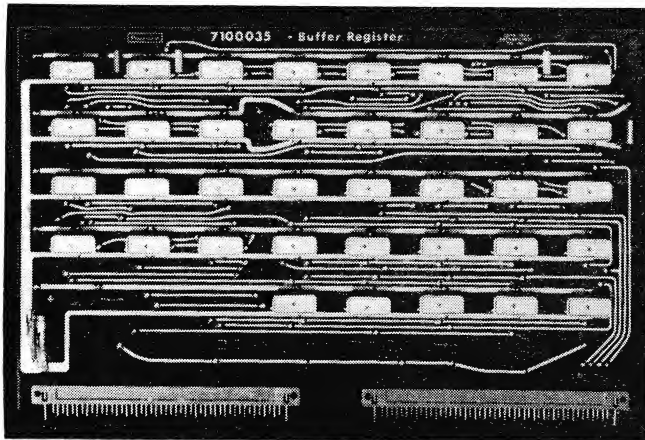
Of the many anticipated difficulties, only the noise problem materialized in practice. All of the conventional wiring and grounding techniques did not appear to

provide the 100-percent assurance against spurious noise triggering required for the equipment. The problem was solved by brute force methods, involving special power line filters to each circuit card and a redesigned clock circuit providing a shaped pulse with a very short-duration "down" time.

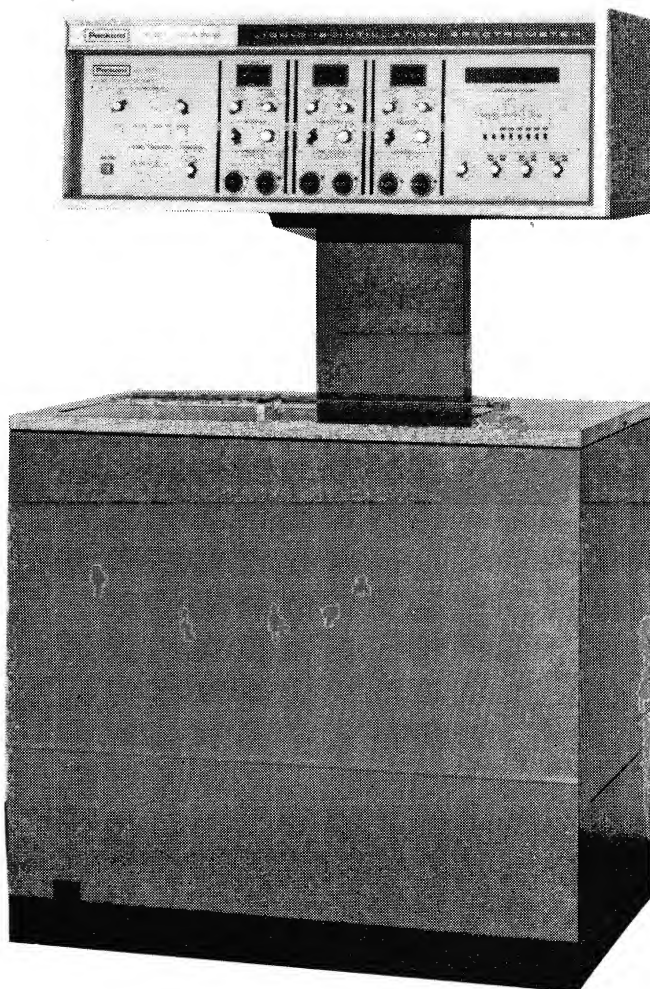
Cubic's experience uncovered a lot of data that will serve them well in subsequent, planned integrated circuit projects. There's the

discovery, for instance, that it takes 1.6 connector pins for every integrated circuit module on a double-sided, printed card — regardless of the type of digital integrated circuit modules involved. There's the fact that an additional inspector on the assembly line, and perhaps some preliminary orientation of assembly-line workers, can save considerable expense in end-of-the-line troubleshooting and repair. Cubic also realized that integrated circuits produced by different manufacturers, though they may meet the same general specifications, are not necessarily identical. The Motorola line of RTL circuits consistently yielded such an extremely low reject rate that Motorola was selected as the source for the vast majority of circuit and system needs.

BUFFER register module used by Packard is quite large.



THE USE of ICs in the Packard radiation counter made it possible to add computational features at no increase in space.



Packard Instrument: More For the Same Money

PACKARD INSTRUMENT COMPANY is a progressive instrument manufacturer. It recently has announced a new radiation counter, Model 3375 Liquid Scintillation Spectrometer. This instrument employs integrated circuits to perform "on-line" data reduction and computation. In essence ICs permitted Packard to increase equipment capability at no appreciable increase in cost or space.

Taking into account assembly cost and the factor of purchasing a year's supply of type 73 Texas Instrument circuits, chief engineer Howard Sterling says IC modules are costing Packard 25 percent less than would conventional circuits. This cost reduction has enabled the incorporation of several new features and capabilities without the necessity of a corresponding increase in selling price.

Packard finds the cost to design with ICs is less. As Sterling puts it, "We don't need an engineer to figure out resistance and capacitance values." More time is necessary to lay out the PC board. A fairly large PC board is used by the company containing two 47-pin Elco connectors. A buffer register contains 37 IC packages.

Packard uses a few conven-

tional components. For example, a transistor is used as a driver to reset a number of decades.

No performance was sacrificed; rather, new functions were gained. Sterling found no problem in compatibility. TI series 73 (modified DTL) were used mostly; a few 74 (TTL) circuits will be introduced later. Full decade counter modules are about the most complicated circuits used. Ten-input gates requiring 16-pin packages are used.

A new low level power supply had to be built. The current requirements are pretty hefty—over 1 Amp at 4 Volts.

One of the problems encountered was getting rid of transients that might damage ICs. Transistors could withstand voltage spikes of 40 V; with ICs they should be kept below 5 V. To be on the safe side, Packard did convert relays from ac to dc. Further, coil transients were suppressed by using diodes and contact spikes bypassed by RC networks. Sterling also says good RFI practices were followed.

The plug-in package was selected because the flat pack was too small to handle readily. Packard Instrument didn't like the straight pins of the TI package; it afforded no opportunity for top-of-the-board probing. (The same objection applies to TO-5 cans.) Consequently Packard ordered the TI package with leads containing a 45° bend. This put the pin rows 300 mils apart and leads can be probed from the top side.

Packard has experienced some difficulty in soldering in the plug-in units. Iron temperature must be held quite close. This problem will probably be remedied by different lead plating. The objective is to wave solder the PC boards.

Packard initially considered three suppliers — a fourth was quickly rejected when samples proved unstable. Texas Instruments was selected for a number of reasons. TI offered the widest variety of devices wanted, the vendor had been a satisfactory transistor supplier, and they offered technical support. Delivery commitments were considered marginal. Their price was about as good as anybody else's. (One decoder nixie driver is purchased

from Fairchild since TI didn't have a suitable unit.)

The key people involved were the project engineer (a digital systems engineer) and the chief engineer. The vice president of manufacturing and the president of the company were consulted (this top management "blessed off" the selection of the source and the price).

The engineering people handled the negotiations. The company is not worried about the sole source situation.

Dero: Calculator Under \$1000

THE SAGE I ELECTRONIC CALCULATOR manufactured by Dero Research and Development Corp. is a low-priced machine recently introduced to the market. It weighs only 12 pounds and contains both conventional and integrated circuits. The Sage I is less than one-half the weight of any other electronic calculator and a third or less the weight of most mechanical machines. It is the first ten-key keyboard electronic calculator, and the first U.S.-made unit to be offered at a price of under \$1000 (\$995.00).

The cost of integrated circuits used on the Sage I are roughly about the same at the present time as are discrete component circuits. However, savings are realized from an assembly standpoint as one integrated circuit replaces 20 or more discrete components. Logic boards have been reduced from six to four with the use of ICs. A proportionate amount of board assembly time is thus saved.

ICs offer obvious savings in incoming inspection as the number of units received are reduced. Some saving is also made in final assembly inspection as the number of boards used is less as well.

From an engineering cost consideration, Dero feels it's no more expensive to design using ICs than it is to design with conventional circuits. In the case of the Sage I, however, some additional cost was experienced as the original design did not include ICs. This extra

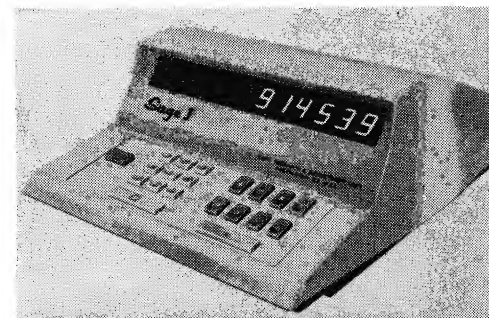
cost was considered "insignificant."

Dero feels indirect savings will accrue because of less testing, savings in space, and in tooling other parts of the unit.

No performance sacrifices or trade offs were made. Performance improves in that there is more "fan-out," i.e., each IC can drive more loads, so less buffers are required. In effect, the extra transistors on the IC chip are used to reduce total circuitry.

No noise immunity problems were encountered (the circuitry of Sage I is relatively slow). The IC end product was basically the equivalent of the former discrete component model.

The simplest possible level of circuit complexity per chip was selected as such devices were less expensive. The Sage I uses only one type of integrated circuit



DESK TOP Dero calculator uses only one type IC.

throughout. The package is a dual-in-line with 14 leads.

Just about all suppliers of ICs were considered. However, only three were considered seriously. One was selected (Signetics), "mostly on the basis of price, but obviously on quality as well," Dero said.

A vendor survey was conducted by the director of research and the director of purchasing. These two men and the president of the company made the final decision. The IC was made from a Dero mask.

Dero, unlike some others, feels that the value of IC in the saleability of the Sage I is quite high. Informed laymen seem to be aware of "microminiaturization" of electronic components and are impressed that the Sage I utilizes the most modern circuitry.

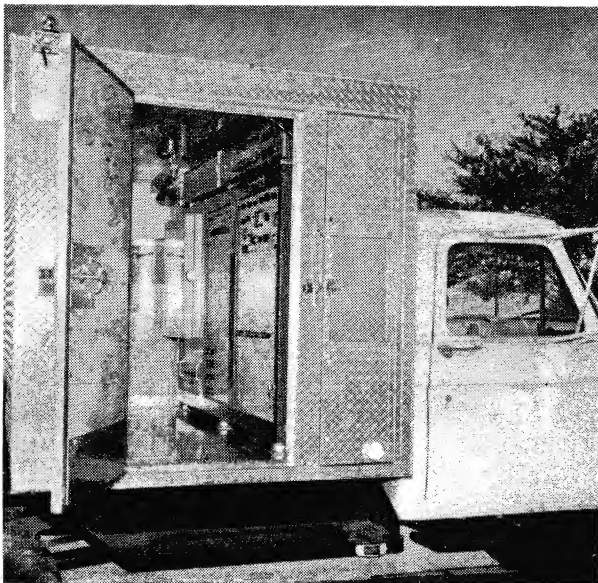
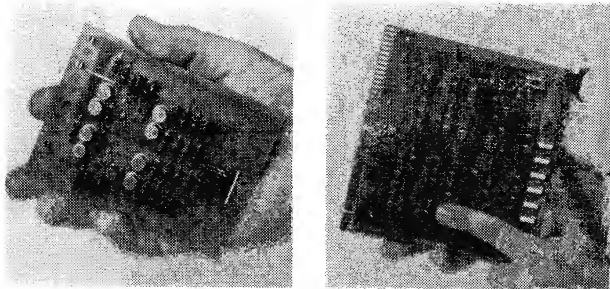
Instruments: More For Less

ONE COULD DOUBT whether instrument divisions of semiconductor manufacturers are objective sources of information. Nevertheless, the experiences of these groups offer much of value.

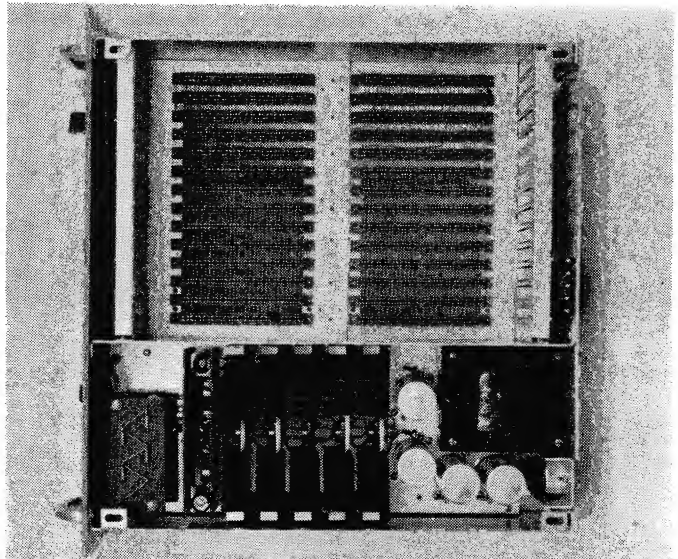
Fairchild Semiconductor created a stir among instrumentation manufacturers in November 1964, when it announced a new digital voltmeter (Model 7100) that made extensive use of integrated circuits. This was the first commercial instrument (price \$2000) that used ICs. Moreover, the use of ICs made possible a new integrating technique (double-ramp integration) that permitted operation in the presence of high peak noise and cross-over effects.

Accuracy was made independent of drift in capacitance or re-

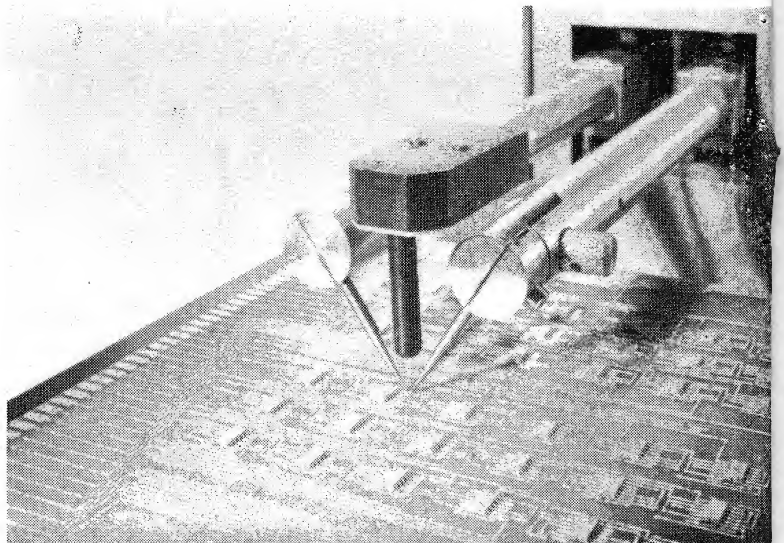
THE DISCRETE components on the PC board (left) have been eliminated through the use of the two integrated circuits at the tip of the finger on the board (right). This board full of ICs is used in the DFS 10,000 (Digital Field System) seismic analyzer.



THE DIGITAL VOLTMETER by Fairchild was earliest commercial test equipment to use integrated circuits.



OVERHEAD VIEW of the TI 848 A-D converter multiplexer, showing how the circuit cards plug in to the chassis.



MODEL 730 circuit bonder by TI uses infrared detector to regulate temperature. ICs can thus readily be bonded to board without damage.

sistance since change of these parameters is canceled out in the dual integration.

A single PC board in the DVM contained the entire readout decade counter circuitry including tube driven circuits.

An A-D converter which is 80 percent integrated circuits, was announced by TI's Industrial Products Group of Houston in March. It undersells its discrete component predecessor by \$1000. The units are not exactly equivalents; the IC is slower (30,000 conversions per second compared to 57,000) but it has 15-bit accuracy compared to 13-bit for the older model. The newer version, the 848, does offer considerably more capability per chassis — 96 single coded multiplexer channels are added all in the same rack.

Don Venker, project manager, says use of ICs saved the division money because it forced engineers to use standard flip-flops. Heretofore every new design had a different flip-flop. Showing supreme confidence in its source, the Industrial Products Group does no incoming inspection. Series 53 modules are purchased.

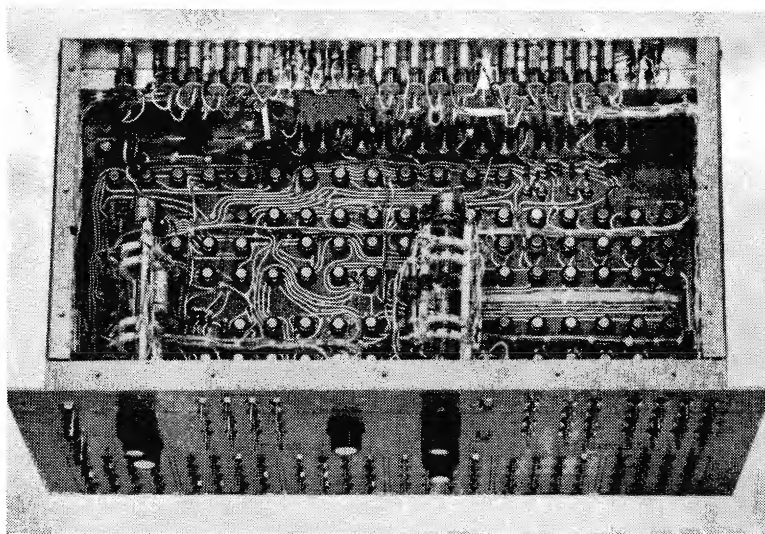
A two-sided board is used. Flat packs are soldered to the board using the new 730 circuit bonder by TI. (By using infrared detection, the new instrument controls joint temperature — 0 ± 3 percent or better — automatically, once initial settings are made.)

Other TI industrial products to use ICs include a new dynamic test system Model 553 and for seismic applications a digital field recording system (DFS/10,000). ICs reduced the size of these units by about $\frac{1}{3}$ (the DFS is suitable for mounting in mobile units).

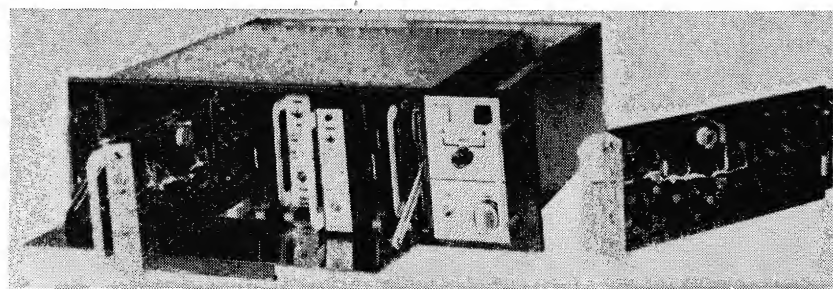
The DFS gives testimony to IC ruggedness. Circuits operate from freezing to 130°F assuring operation in the arctic or on the Arabian desert.

Joining The Parade

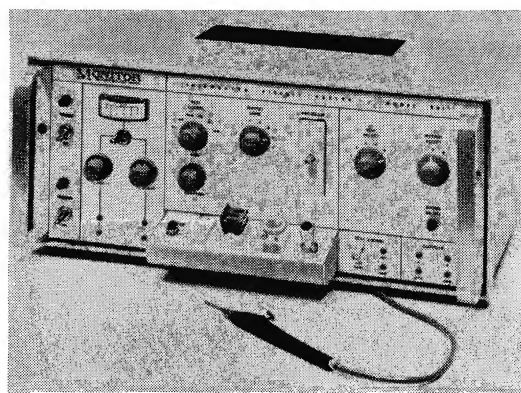
THE ANNOUNCEMENTS OF COMMERCIAL CIRCUIT MODULES or equipments that now use ICs are numerous. Here are a few of the recent ones. **TV Sync Generator** — A new synchronizing pulse generator and power supply de-



THE DESIGN of the program generator module in the Computer Test Corp. current pulse generator is built around Fairchild 10 MHz micrologic integrated circuits (which are responsible for the high speed 5 MHz operation).



SYNC PULSE GENERATOR introduced by Dage-Bell Corp. uses integrated circuits and completely solid state circuitry to provide composite sync, mixed blanking, and horizontal and vertical drives for television broadcasters.



MONITOR SYSTEM's integrated circuits tester uses integrated circuits.

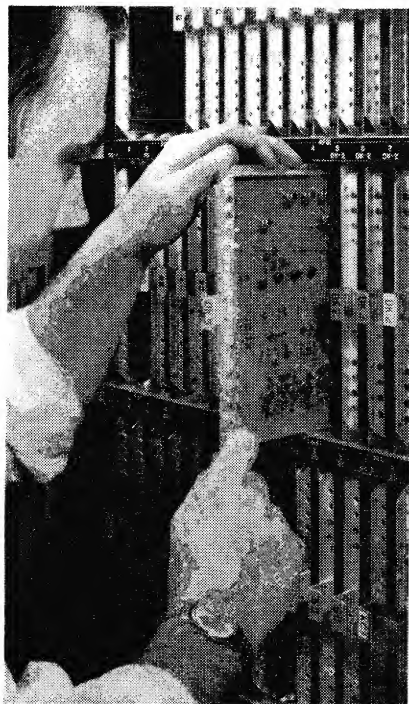
veloped by Dage-Bell Corp., a subsidiary of Raytheon, uses integrated circuits to achieve reliability and compactness. The standard 19-inch rack unit is only 5- $\frac{1}{2}$ inches high.

Programmed Current Pulse Generator — 5 MHz integrated circuit logic cards are used in memory testers built by Computer Test Corp. Program generator model 1550 provides an 8 step pulse

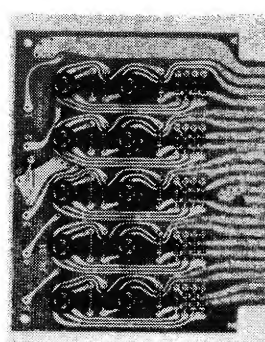
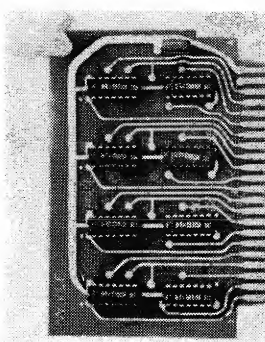
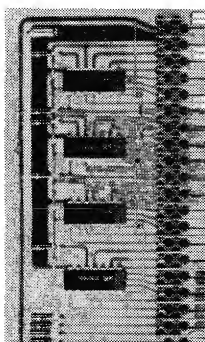
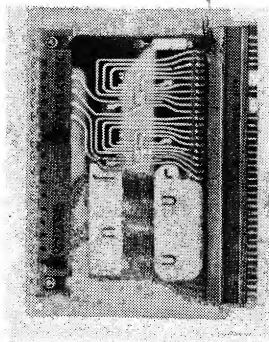
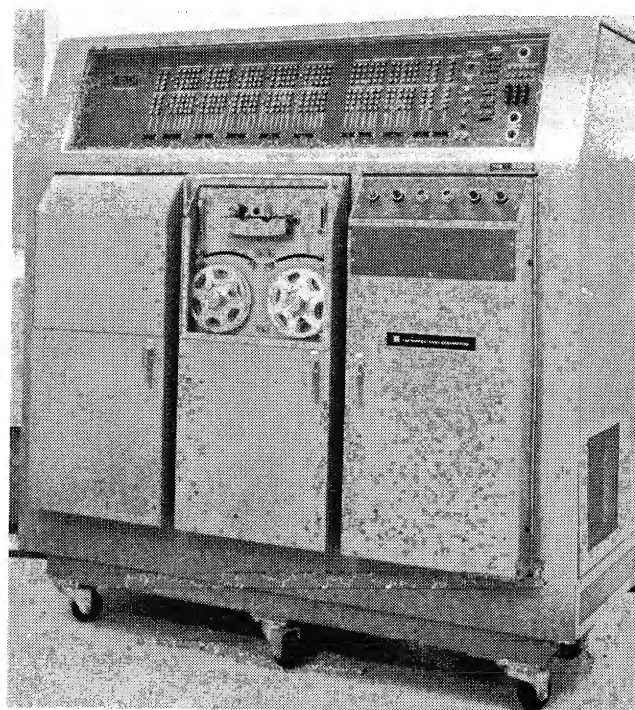
sequence. Model 1700 is a 16 step unit. ICs permit a high degree of programming flexibility and high pulse rates.

Integrated Circuit Tester — A table top dynamic IC tester by Monitor Systems selling for under \$2000 uses some ICs for pulse generation and control along with standard circuitry (for clock control). The ICs are flat pack DTL type purchased from both Fair-

TYPICAL integrated circuit module in Bunker-Ramo's newly redesigned 3000 numerical contouring control.



MODULES below, left to right, are products of Monitor Systems, Decision Control, Wyle, and Computer Logic (see text).



child and Texas Instruments.

Numerical Contouring Control — Use of integrated circuits in the new Model N/C system by Bunker-Ramo Corp. has substantially reduced the number of modules required — in a typical 3-axis system, for example, the reduction is from 96 modules to 55. This application, however, contrary to others reported, did not result because of economics.

Dean W. Freed, General Manager of Bunker-Ramo's Numerical Control System Div., says, "Microminiature circuitry gives a higher frequency capability because of shorter leads between components and the smaller size of their junctions, and a more reliable operation because of the elimination of hundreds of individual components and connections. In addition it makes possible higher density of packaging, which in turn gives more flexibility in

inserting options into the system without requiring a larger cabinet. It ultimately may result in a lower over-all cost."

In the 3000 system, integrated circuits are used primarily in the feed rate generator section and in the interpolator—areas where high frequency is most needed and the dense complexity of the circuitry makes possible the greatest reduction in the number of modules.

Operational Amplifier — Burr-Brown offers operational amplifiers featuring over voltage and short circuit protection as well as internal phase stabilization.

Logic Modules — DTL logic circuit boards are offered by Monitor Systems, Inc., Fort Washington, Pa. (25 cards); Decision Control, Inc.; Newport Beach, Calif. (20 cards); and Wyle Laboratories, El Segundo, Calif. (15 cards). Computer Logic Corp. has a series of five universal JK flip-flops which

use plastic encapsulated ICs.

Another large computer producer that has announced heavy uses of ICs is Burroughs. Burroughs uses ICs of the complementary transistor logic type to achieve from moderate to extremely high-speed operations with relatively low price. Although CTL was a joint development of Fairchild and Burroughs, it is not sacred as a logic form. The 500 systems use CTL but other systems may not. The optimum logic, according to Burroughs engineers, depends on the system and the ingenuity with which standard units are combined and interconnected.

One interesting aspect of the new 500 system is the scratch pad memories used in the central processor unit. This memory for single operations obviates the need to shuttle back and forth between main memory units and the central

processor. Although the current scratch pad memory is said to be relatively small, this area offers ripe opportunities for the higher complexity ICs now becoming more prevalent.

Military users are finding commercial uses of integrated circuits. Collins Radio is an example. Collins reports that by the end of the year, many commercial products will use microelectronic devices, thin-film circuits, monolithic ICs or hybrids. Here is what Collins recently said about costs:

Thin-film samples can be manufactured at a cost of \$500-\$1000. Quantities of 5 to 50 vary little in total cost. The same samples by monolithic IC techniques would cost \$10-30,000.

The situation is reversed in mass production. Monolithic ICs can be bought for \$2-3 up to \$25-30 each depending on circuit complexity. Thin-film hybrid ICs in mass, cost \$10 to \$40 each.

But, the hybrids generally perform more functions per unit, reducing the price differential in practice. Circuits using 100 percent discrete components in quantity cost more than either type IC.

Because of the monolithic IC cost advantage, they are the logical choice for production needs if their speed and precision meet system requirements.

Most of the ICs used for economy reasons are the digital type (exception—the operational amplifier by Burr-Brown and sense amplifiers used by computer companies). If integrated circuits are to play anything other than a sales gimmick role in entertainment products such as radio and TV sets, they will have to be cheap. RCA in March announced four economy line integrated circuits for FM receivers and other wide-band sound applications.

The wideband amplifier and amplifier discriminator circuits of-

fered contain 39 components on a single chip. RCA says these circuits can sell for around \$1.25 in quantity. Such prices certainly suggest that ICs will find their way into consumer products perhaps earlier than the predicted date of 1968.

Sore Spot: Single or Dual Source

A SORE SPOT IN THE INDUSTRY is the subject of dual sources (no one ever dreams of more than two). A soft spot of this report is that we can't deal adequately with the subject.

The name of the game, said one procurement manager, who must remain anonymous, is single source. No two vendors' circuits are identical, he said, and often not interchangeable, even though they are presumably designed to the same spec. This situation is likely to hold until suppliers use identical processes and process control.

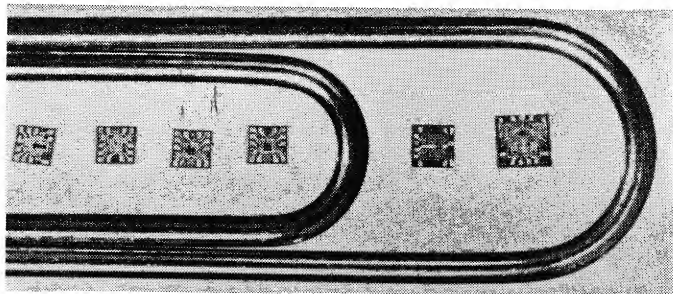
Buyers are at work trying to get dual sources lined up but in the meantime they fervently hope, fingers crossed, that the principal supplier can meet his commitment and will not have something go haywire with his line.

When a second source is a licensee of the first, there is hope that interchangeable circuits can be made. Such licensing is happening. (Fairchild has licensed a number of companies, for example.) The recent announcement by Signetics and Sprague that the latter will produce Signetics circuits with their part numbers is a hopeful sign.

In the absence of such agreements, one must wait for more process maturity—which can be accelerated by hiring and poaching of key people. The military's demands for dual sources is apparently being met but few are talking about yield and rejects.

Until such time as single source patterns are broken, the buyer must exhibit extreme care in making sure the supplier understands and can fulfill the buyer's requirements.

EP



APPROXIMATELY 9000 of the small integrated circuits above are used in the central processing of the new Burroughs 2500 data processing systems.



